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# BSC

# Scientific Analysis Administrative Change Notice



*Complete only applicable items.*

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| 1. Document Number: | ANL-MGR-GS-000002 | 2. Revision: | 02 | 3. ACN: | 01 |
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| 4. Title: | Characterize Eruptive Processes at Yucca Mountain, Nevada | | | | |
| 5. No. of Pages Attached: | 11 | | | | |

| 6. Approvals: | | | |
|---|---|---|---|
| Preparer: | Paul E Sanchez<br>Print Name and Sign | SIGNATURE ON FILE | 4-25-05<br>Date |
| Checker: | Cheryl Hastings<br>Print name and sign | SIGNATURE ON FILE | 4/25/05<br>Date |
| QER: | Judy Gebhart<br>Print name and sign | SIGNATURE ON FILE | 4/26/05<br>Date |
| Responsible Manager: | Mike Cline<br>Print name and sign | SIGNATURE ON FILE | 4/26/05<br>Date |

| 7. Affected Pages | 8. Description of Change: |
|---|---|
| 4-1 | To resolve CR 4231, insert additional direct input DTN with table footnote<br><br>page 4-1, Table 4-1, insert after row 2, the following text in the defined columns (bolded) with table footnote:<br><br>**Data Used**<br><br><u>Background $^{137}$Cs concentrations on stable alluvial surfaces around Yucca Mountain</u><br><br>**Application of Data**<br><br><u>Reference $^{137}$Cs soil profile used to estimate erosion on specific geomorphic surfaces present on Fortymile Wash alluvial fan.</u><br><br>**Data Source**<br><br><u>LA0302CH831811.002 [DIRS 162863][1]</u><br><br>**Location in Report**<br><br><u>Section 6.3.4.2.2</u><br><br><u>[1]DTN contains analytical results for 66 $^{137}$Cs soil samples. The first 15 sample results listed in the DTN define the reference profile for a stable soil surface. This reference profile is compared with the remaining 51 $^{137}$Cs soil profile in the DTN to determine erosion rates on specific geomorphic surfaces.</u> |

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| | |
|---|---|
| 4-1 | To resolve CR 4231, make the following changes<br>page 4-1, Table 4-1, row three, make changes identified in the defined columns (bolded) and add footnote on DTN as indicated:<br>**Data Used**<br>~~66~~ Interpretation of $^{137}$Cs profile values for samples from ~~analyses for~~ Fortymile Wash alluvial fan in Amargosa Valley<br>**Application of Data**<br>~~Calculation of erosion rate for~~ Determination of amount of erosion on specific geomorphic features ~~ash redistribution~~ ~~analyses~~ ~~in a YMR drainage~~ within Fortymile Wash alluvial fan to support erosion rates for ash redistribution abstraction<br>**Data Source**<br>LA0308CH831811.002 [DIRS 164853] [2]<br>**Location in Report**<br>~~Section 6.3.4.2.3~~ Section 6.3.4.2.4<br>[2]DTN contains estimates of erosion on specific geomorphic surfaces present in Fortymile Wash alluvial fan for 51 $^{137}$Cs samples. Used to support erosion rate on interchannel divide areas (Section 6.3.4.2.5) |
| 6-5 | To remove TBV-6840, please make following corrections and addition of sentence<br>page 6-5, paragraph 1, Sentence 2<br>Details of the inclusion ~~or exclusion~~ of igneous disruptive events FEPs are discussed in *Features, Events, and Processes: Disruptive Events* (BSC, 2004 [DIRS 170017] Sections 6.2.1.7; 6.2.2.2; 6.2.2.3; 6.2.2.4; 6.2.2.6; 6.2.2.7; 6.2.2.8). The rationale for exclusion of igneous disruptive events FEPs are also discussed in *Features, Events, and Processes: Disruptive Events* (BSC, 2004 [DIRS 170017] Sections 6.2.2.1; 6.2.2.5; 6.2.2.9). |
| 6-9 | To remove TBV-6053, please make the following change<br>page 6-9, paragraph 1, sentence 3 (Section 6.3.1.1)<br>*Dike/Drift Interactions* (BSC 2004 [DIRS 170028] Section 6.4.5) uses numerical modeling to show that when rising magma intersects an open drift, there will be a short period of time (on the order of several minutes) during which magma flows into the drift ~~(potentially explosively)~~ before the magma reaches the ground surface.<br>~~such that the upward-propagating magma front moves more slowly directly above the drift than above adjacent pillars~~<br>**Additional Explanation for above change:**<br>Section 6.4.1 states "The magma entering the drift from the dike is considered to be partially degassed so that it does not explosively decompress……It is consistent with observations (at Hawaii and at Parícutin in Mexico) of magma behavior prior to magma reaching the surface.<br>Section 7.3.1.1 states "Comparisons with field observations at Paricutin support the phenomenology described in the model".<br>Section 6.5.2.3 states hydrovolcanic breakout is unlikely<br>Breakout is out of context |

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|---|---|
| 6-12 | To resolve TBV-6052, make the following changes<br>page 6-12, last paragraph, second sentence<br>The PVHA calculated the mean annual frequency of intersection of the repository by a volcanic event as 1.7 x $10^{-8}$ per year (BSC 2004 [DIRS 169989] Table 7-1 ~~Table 22~~). |
| 6-14 | To resolve CR 4231, make the following changes<br>page 6-14, paragraph 2, add sentence following last sentence, as shown<br>Table 6-2 lists statistical parameters associated with the 12 most abundant oxides from these analyses. The 45 analyses chosen represent the best lithologies in the interiors of dense basalt flows suitable for accurate chemical analyses (ie. other samples screened due to effects of oxidation or other alteration). |
| 6-45 | To resolve CR 4231, insert reference to DTN in text<br>page 6-45, paragraph 5, insert sentence following sentence 3:<br>Samples were collected at four locations along Fortymile Wash and within Crater Flat (Figure 6-10). Analytical results for the 15 reference samples are archived in DTN LA0302CH831811.002 [DIRS 162863]. |
| 6-47 | To resolve CR 4231, insert source DTN as Figure 6-13a footnote<br>page 6-47, Figure 6-13, insert DTN as source to Figure 6-13a<br>(a) Typical 137Cs Reference Sample Profile with Depth in Soil<br>Source: DTN: LA0302CH831811.002 [DIRS 162863]. |
| 6-54 | To resolve CR 4231, make the following changes<br>page 6-54, Table 6-9, row three, make changes identified in the identified column (bolded)<br>**Input Description**<br>~~66~~ ~~a~~Analytical concentrations of $^{137}$Cs in samples from locations on different geomorphic features on a major YMR drainage alluvial fan. |
| 8-13 | Add DIRS 162863 to Reference list. |
| B-13 | paragraph 4, sentence 3<br>Effects of storms and climate changes on natural soil redistribution processes are described in Section 6.3.4.3 ~~6.3.4.4~~. |
| C-7 | To resolve CR 4231, make the following changes<br>page C-7, Table C-2, add sentence following sentence 2 in note, as shown<br>Elevations reflect relative stratigraphic position (early to late cone activity), as explained in the text. Mean values are calculated for samples collected at the same or similar elevation. |

# 4. INPUTS

## 4.1 DATA, PARAMETERS, AND OTHER INPUTS

In this scientific analysis report, all available scientific literature is reviewed and from this data parameter values, distributions, and theoretical concepts are developed. This information is used to recommend parameter distributions for models and analyses that support the YMP total system performance assessment (TSPA) calculations. Parameter distributions are based on field data and data available in published sources. In cases where there are insufficient published data, parameter distributions are recommended that conservatively capture the expected range with consideration of the author's judgment, external reviews, and expert elicitations. Data derived from field observations, sampling, and laboratory measurements are used to infer the volcanic history of Lathrop Wells volcano, including volume calculations for effusive and explosive products. Brief descriptions of the data used as input are listed in Table 4-1. Data from external sources that are used as direct input are listed in Table 4-2. Data from these sources have been justified per the requirements of AP-SIII.9Q, and are considered to be qualified for intended use. These justifications are documented in Appendix A. Qualification status of the input data is indicated in the DIRS database.

Table 4-1. Data Used as Inputs for Calculations in This Scientific Analysis Report

| Data Used | Application of Data | Data Sources (Data Tracking Number) | Location in This Report |
|---|---|---|---|
| Dike length distribution for intersection with the repository | Calculation of maximum magnitudes of dike-induced earthquakes | LA0009FP831811.001 [DIRS 164712] | Section 6.3.1.3 |
| 45 chemical analyses of products from Lathrop Wells volcano | Calculation of mean chemical composition of Lathrop Wells products | LA000000000099.002 [DIRS 147725] | Section 6.3.2.1 |
| Background $^{137}Cs$ concentrations on stable alluvial surfaces around Yucca Mountain | Reference $^{137}Cs$ soil profile used to estimate erosion on specific geomorphic surfaces present on Fortymile Wash alluvial fan | LA0302CH831811.002 [DIRS 162863][1] | Section 6.3.4.2.2 |
| Interpretation of $^{137}Cs$ profile values for samples from Fortymile Wash alluvial fan in Amargosa Valley | Determination of amount of erosion on specific geomorphic features within Fortymile Wash alluvial fan to support erosion rates for ash redistribution abstraction | LA0308CH831811.002 [DIRS 164853][2] | Section 6.3.4.2.4 |
| Tephra thickness data for Lathrop Wells | Calculation of the eruption volumes of YMR volcanoes | LA0305DK831811.001 [DIRS 164026] | Section C4 |

1 DTN contains analytical results for 66 $^{137}Cs$ soil samples. The first 15 sample results listed in the DTN define the reference profile for a stable soil surface. This reference profile is compared with the remaining 51 $^{137}Cs$ soil profile in the DTN to determine erosion rates on specific geomorphic surfaces.

2 DTN contains estimates of erosion on specific geomorphic surfaces present in Fortymile Wash alluvial fan for 51 $^{137}Cs$ samples. Used to support erosion rate on interchannel divide areas (Section 6.3.4.2.5).

Application (TSPA-LA) through the use of the results of the calculations described in this document. Details of the inclusion of igneous disruptive events FEPs are discussed in *Features, Events, and Processes: Disruptive Events* (BSC 2004 [DIRS 170017] Sections 6.2.1.7; 6.2.2.2; 6.2.2.3; 6.2.2.4; 6.2.2.6; 6.2.2.7; 6.2.2.8). The rationale for exclusion of igneous disruptive events FEPs are also discussed in *Features, Events, and Processes: Disruptive Events* (BSC 2004 [DIRS 170017] Sections 6.2.2.1; 6.2.2.5; 6.2.2.9).

For the igneous eruptive scenario, the TSPA-LA assumes that a hypothetical dike propagates upward, intersects the repository, provides a source for magma to enter the repository drifts, and magma and ash, potentially with entrained waste, are released to the surface via an eruptive conduit. The FEPs listed in Table 6-1 are part of the conceptual basis for such a scenario. However, this report does not provide a direct basis for the inclusion in TSPA-LA of the FEPs listed in Table 6-1, with the exception of parameters developed to address ash redistribution. This report provides supporting analyses to help constrain the potential consequences of the listed FEPs. As such, a partial treatment of the included FEPs is provided herein, and the results of this analysis report and listed FEPs are considered to be implicitly included in the TSPA-LA. It has been determined that the *Technical Work Plan: Igneous Activity Assessment for Disruptive Events* (BSC 2004 [DIRS 171403], Table 5) does not reflect the current FEPs applicable to this analysis report. The current FEPs that are applicable to this report are listed in Table 6-1.

Table 6-1. Disruptive Events Included FEPs for This Scientific Analysis Report

| FEP Number | FEP Name | Relevant Section(s) |
|---|---|---|
| 1.2.03.03.0A | Seismicity associated with igneous activity | 6.3.1.3 |
| 1.2.04.03.0A | Igneous intrusion into repository | 6.3.1.1; 6.3.1.2; 6.3.2.1; 6.3.2.3; 6.2.3.4; 6.3.3.1; 6.3.3.2 |
| 1.2.04.04.0A | Igneous intrusion interacts with EBS components | 6.3.2.1; 6.3.2.2; 6.3.2.3; 6.3.2.4; 6.3.3.1; 6.3.3.2; 6.3.3.3; 6.3.3.5 |
| 1.2.04.06.0A | Eruptive conduit to surface intersects repository | 6.3.1.1; 6.3.1.2; 6.3.2.1; 6.3.2.2; 6.3.2.3; 6.3.2.4; 6.3.3.1; 6.3.3.4 |
| 1.2.04.07.0A | Ashfall | 6.3.3.4; 6.3.3.6 |
| 1.2.04.07.0C | Ash redistribution via soil and sediment transport | 6.3.4 |

Source: DTN: MO0407SEPFEPLA.000 [DIRS 170760]

EBS = engineered barrier system

## 6.3 ERUPTIVE PROCESSES ANALYSIS

There are several characteristics of igneous activity that need to be constrained in order to predict potential consequences of a volcanic event were one to occur at Yucca Mountain. These are:

- Geometry of shallow intrusive features such as dikes and conduits
- Maximum magnitudes of dike-induced earthquakes
- Properties (e.g., composition, density, viscosity, temperature) of magmas that might interact with repository structures and materials
- Dynamic processes associated with magma ascent at shallow depths and subsequent eruption

It is uncertain whether the intersection of a dike with a repository drift would result in the development of a volcanic conduit that is localized and/or elongated along the drift. The issue is difficult to assess because there is no information from analogous systems in which a basaltic dike intersected a long drift-like void, nor is there a theoretical treatment of the scenario in the literature. *Dike/Drift Interactions* (BSC 2004 [DIRS 170028], Section 6.4.5) uses numerical modeling to show that when rising magma intersects an open drift, there will be a short period of time (on the order of several minutes) during which magma flows into the drift before the magma reaches the ground surface. However, the time scale for drift pressurization or filling is only a few minutes, a very short period of time compared to the expected duration of a volcanic event (1 day to 15 years; Section 6.3.3.4), and it is not clear that such short-duration processes would have much of an effect on conduit formation.

Some volcanic conduits, now eroded and exposed at the surface as necks or plugs, are elongated along their host dikes. This might represent an incomplete transition from a dike-fed fissure eruption to a fully developed, roughly circular conduit (rather than the evolution of an originally circular conduit to an elongated one). However, the elongation of a conduit along its host dike, which commonly resides in a self-generated vertical fracture, is not completely analogous to the case of a dike intersecting a repository drift. The host fracture provides a zone of weakness with substantial vertical extent over which magma-flow patterns, focusing of magma, and conduit enlargement can develop, whereas a drift on the order of 5 m in diameter would provide limited time for development of erosive flow.

Because of the uncertainties and lack of published information on conduit localization and/or elongation, there is no basis for providing a statistical weighting for the location of conduits that might form within the repository footprint. It is recommended that the location of a potential conduit be treated as a random process within the repository footprint. It is assumed that the range of values for circular conduit diameter encompasses the length of potential conduit elongation. In this manner, conduit elongation is implicitly treated because the circular cross section of a conduit allows interaction with additional drifts besides the set of drifts that are initially intersected.

### 6.3.1.2 Dike Swarms

Volcanoes in the YMR are fed by one main dike along which a central cone and other vents may form, but subsidiary dikes are also present. For example, the Lathrop Wells volcano may be underlain by three dikes (inferred from Perry et al. 1998 [DIRS 144335], Figure 2.10):

- The dike that fed the main cone and small spatter vents in a chain to the north and south of the cone
- A dike that fed spatter and scoria mounds in a parallel chain just to the east of the main dike

The maximum magnitudes estimated for the YMR are consistent with maximum-magnitude estimates derived from surface lengths in volcanic rift zones worldwide and the eastern Snake River Plain. They exceed estimates based on observed seismicity at active volcanic rift zones and fault widths in volcanic rift zones worldwide, the eastern Snake River Plain, and a 4-km volcanic crust (Figure 6-1). Magnitudes of dike-induced earthquakes that are calculated using tectonic-fault dimensions will be maximum magnitudes, for the following reasons (Smith et al. (1996 [DIRS 101020], p. 6,284-6,285):

- The crustal rigidity of the shallow, fractured crust in active volcanic areas is probably lower than the rigidity of typical midcrustal regions where most tectonic fault ruptures nucleate
- Commonly high b values (> 1.0) are associated with volcanic seismicity, indicating the effective differential stress in the shallow crust of active volcanic regions is lower than for typical midcrustal regions (b is the slope of the Gutenberg-Richter magnitude-frequency relationship $\log N = a - bM$; where M is magnitude; N is the number of earthquakes with magnitudes greater than M occurring in a given time period; “a” and “b” are constants that describe the linear relationship, “a” is the intercept)
- Rupture along dike-induced normal faults and fissures occurs incrementally rather than as a sudden catastrophic release of strain, where only the latter gives rise to energy release that is proportional to the dimensions of the entire fault rupture.

For example, surface faulting with well over 1-m displacement was observed to accompany a fissure eruption near Krafla caldera in Iceland, but the associated earthquakes did not exceed magnitude 2.5 (Brandsdottir and Einarsson 1979 [DIRS 155852], p. 209).

Smith et al. (1996 [DIRS 101020], p. 6,287-6,288) selected a maximum magnitude for dike-induced earthquakes in the eastern Snake River Plain to be consistent with the maximum magnitudes derived from fault width and rupture area. They reasoned that the maximum magnitude estimates derived from fault width and rupture area measured in the eastern Snake River Plain were internally consistent, and they were consistent with observed magnitudes during dike injection in worldwide volcanic rift zones. Following this approach, the maximum magnitudes of 4.8, 5.8, and 6.2 are reasonable estimates for potential dike-induced earthquakes in the YMR. These values represent maximum magnitudes derived from the dike length distribution recommended by the PVHA experts. In the YMR, the state of stress is sufficiently close to failure (Stock et al. 1985 [DIRS 101027], p. 8,701-8,702) that dike intrusion could induce slip on pre-existing faults, generating earthquakes of larger magnitude than the maximum magnitudes of observed seismicity associated with active volcanic rift zones (represented as the mean and one standard deviation for M $3.8 \pm 0.8$ in Figure 6-1).

Not all dike-intrusions produce a maximum-magnitude earthquake, nor will all dikes intersect the repository. The PVHA calculated the mean annual frequency of intersection of the repository by a volcanic event as $1.7 \times 10^{-8}$ per year (BSC 2004 [DIRS 169989] Table 7-1). A maximum magnitude, dike-induced earthquake can be associated with the volcanic event that intersects the repository. Therefore, the recurrence interval of maximum-magnitude, dike-induced earthquakes at the repository is given by the frequency of dike intersection of the repository.

approach is more conservative because it represents a greater potential dispersal of radionuclides (see Section 5, Assumption 1).

The major element variation for Lathrop Wells is based on 45 chemical analyses (DTN: LA000000000099.002 [DIRS 147725]). Table 6-2 lists statistical parameters associated with the 12 most abundant oxides from these analyses. The 45 analyses chosen represent the best lithologies in the interiors of dense basalt flows suitable for accurate chemical analyses (i.e., other samples screened due to effects of oxidation or other alteration).

### 6.3.2.2 Water Content of Primary Basaltic Magma

Eruptive styles in the YMR ranged from violent Strombolian on one end of the spectrum to quiescent a'a' lava on the other (Perry et al. 1998 [DIRS 144335], Chapter 2). Eruption style was primarily controlled by volatile content (which is dominated by water) and the rate at which volatiles were exsolved from the magma. The inferred eruptive styles indicate a large range in volatile contents and, hence, water content of YMR magmas. In addition, variations in energy are suggested at individual volcanic centers such as those of the Quaternary Crater Flat field and Lathrop Wells volcanoes.

Amphibole, possibly of magmatic origin, is found as a rare and sparse phase in some Quaternary Crater Flat basalts. Knutson and Green (1975 [DIRS 106299], Figure 1, p. 126), performing experiments on material similar in composition to YMR basalts, observed that magmatic amphibole was stabilized at water contents of between 2 and 5 wt%. Baker and Eggler (1983 [DIRS 122601], p. 387) showed that at 2 Kbar pressure, water content in excess of 4.5 wt% is required to stabilize amphibole in high-alumina basalt similar to YMR basalts. However, water content substantially greater than 5 wt% is not considered likely because this high water content is most commonly associated with more chemically evolved magmatic compositions (e.g., rhyolite) than those observed in young volcanoes near the YMR. Also, Sisson and Grove (1993 [DIRS 122564], p. 167) note that low-Mg basalts with high alumina content cannot erupt as liquids with water content in excess of 4 wt% because they will exsolve gas and rapidly crystallize to form phenocryst-rich magmas as they approach the surface. Based on this, it is argued that 4 wt% is an upper bound on initial dissolved water content. At the lower end of the range, a'a' lava may form from relatively low-volatile-content eruptions.

Even if a particular concentration of volatiles could be tied to a particular eruptive style, the YMR post-Miocene (i.e., 5 Ma) record is sparse; therefore, it is difficult to rigorously define a probability distribution function for primary magma water content for use in TSPA. The following distribution is recommended:

> No magmatic water has a zero probability of occurrence. This statement reflects our knowledge that very low volatile contents are very rare. The probability should increase linearly from 0 to 1 percent. The probability should be uniform from 1 to 3 percent, reflecting that this is the most likely range of water contents. The probability should decrease linearly between 3 and 4 wt%, so that it is zero at 4 wt%, representing the expectation that at about 4 wt%, basaltic magmas will crystallize before reaching the surface to erupt.

used to examine erosion and deposition rates over this short time period. Uncertainty enters when relating processes and rates acting over a short time period (~50 years) to erosion/deposition over much longer periods (> 1 ky). However, careful examination of where and how modern erosion and deposition are occurring can help elucidate what is likely to occur sometime in the future.

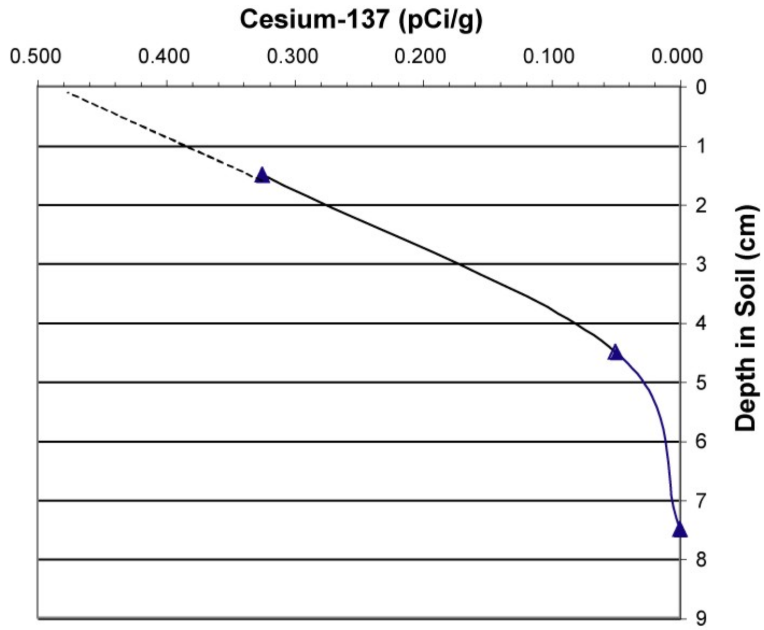
In earlier $^{137}Cs$ landscape-component studies (Chappell 1999 [DIRS 163891], p. 138), the investigated sites were either along transects or on plots of about a dozen square kilometers. The current study examines the movement of sediment through the drainage systems for an area that encompasses several hundred square kilometers, including the Yucca Mountain site and Fortymile Wash alluvial fan (the fan alone encompasses 100 $km^2$). Because of the uncertainties in applying this technique to this large area, the purpose is to note trends or similarities for sites of erosion or deposition.

$^{137}Cs$ attaches preferentially to silt- and clay-size particles in normal sedimentary profiles, but also to dune sand as, for example, in the sands of Big Dune (Amargosa Valley), and to sand grains in small coppice dunes that traverse surfaces of alluvial fans. The cesium analyses discussed below show some of the highest cesium values from these dune materials, which possess almost no fine-grained material.

In the study area, most alluvial surfaces contain a prominent vesicular A-horizon composed of silt with minor amounts of clay, often directly beneath a desert pavement. Because desert pavements develop over thousands of years, they are characteristic of very stable surfaces. Part of this study (the reference sample suite) was designed to verify that $^{137}Cs$ does not infiltrate rapidly into the deeper sediments so that depth profiles among sites could be compared confidently. The remainder of the study examines the cesium quantities in the material, vertical cesium profile, and particle-size composition of the upper 6 to 10 cm of sediments to help determine erosion/deposition rates on the Fortymile Wash alluvial fan surfaces.

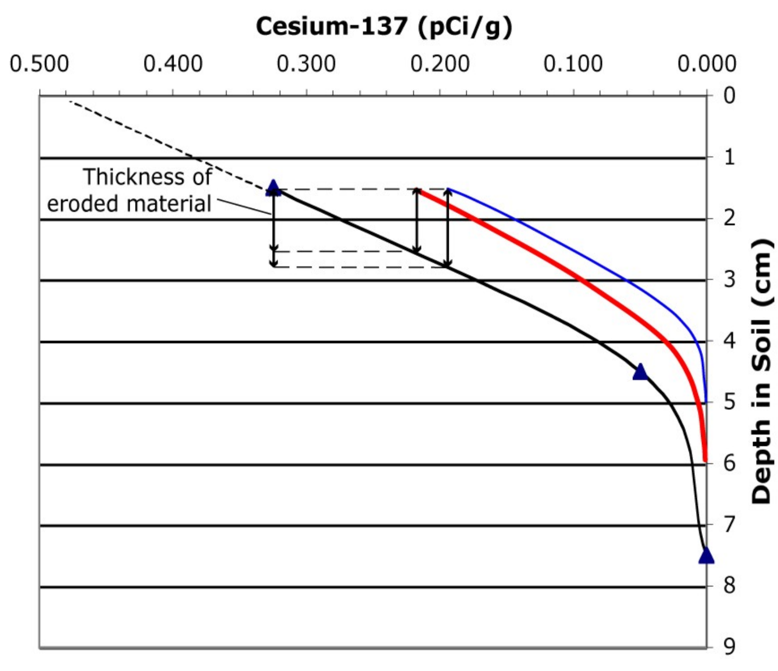
#### 6.3.4.2.2 Reference Sites for $^{137}Cs$ Study

Previous studies using $^{137}Cs$ in North America (Wallbrink et al. 1994 [DIRS 164092], p. 95) did not find a single value that could be used as a calculated background value for every study. Thus, a study was performed to determine the nature of cesium distribution around Yucca Mountain, and reference samples were used to compute the Yucca Mountain background value. Samples were collected at four locations along Fortymile Wash and within Crater Flat (Figure 6-10). Analytical results for the 15 reference samples are archived in DTN: LA0302CH831811.002 [DIRS 162863]. For each sample location, alluvial surfaces were selected based on characteristics associated with their long-term stability, including the presence of a well-developed desert pavement overlying a well -developed, 4 to 6 cm thick, vesicular A-horizon (at least pre-Holocene time or 10,000+ yrs). Two sample locations, about 3 km apart, were located on a high, river-cut terrace in Fortymile Wash, and two sampling sites were located in central Crater Flat, about 2 km west of Yucca Mountain. Sample pits were hand-dug to approximately 0.5 to 0.75 m depth. At each location, three samples were collected from a 0-3, 3 -6, and 6-9 cm depth. Commonly, a caliche layer within the alluvium was visible in the bottom of the pit but was not sampled. Carbonate in the soil at this depth indicates the age of the overlying soil as Pleistocene (10,000+ years) (Gile et al. 1981 [DIRS 144518], pp. 67-68). In addition, the lower alluvium




(a) Typical $^{137}$Cs Reference Sample Profile with Depth in Soil

Source: DTN: LA0302CH831811.002 [DIRS 162863]




(b) Example of $^{137}$Cs Profiles Showing Effects of Erosion

Source: DTN: LA0308CH831811.002 [DIRS 164853].

NOTE: The black line is typical reference sample Cs-137 profile with depth in sediment on the Fortymile Wash fan. The red line represents the Cs-137 profile from which 1 cm of material has been eroded. The blue line represents the Cs-137 profile from which ~ 1 to 1.25 cm has been eroded. The three curves are similar except that the tops of the red and blue curves have been truncated and do not have the upper part that is present on the black curve.

Figure 6-13. $^{137}$Cs Sample Profiles

Table 6-9. List of Input Data and Uncertainty Type

| Input Name | Input Description | Input Source | Value or Distribution | Type of Uncertainty |
|---|---|---|---|---|
| Dike length distribution | Distribution of dike lengths using expert elicitation in the PVHA (CRWMS M&O 1996 [DIRS 100116] Appendix E; Figure 4). | DTN: LA0009FP831811.001 [DIRS 164712] | 0.6 km for 5$^{th}$ percentile; 4.0 km for mean; 10.1 km for 95$^{th}$ percentile | Epistemic |
| 45 chemical analyses of products from Lathrop Wells volcano | Mean major-element chemical composition (and related statistics) of Lathrop Wells lava. | DTN: LA000000000099.002 [DIRS 147725] | Means (see Table 6-2 for complete statistics)<br>$SiO_2$-48.50%<br>$TiO_2$-1.93%<br>$Al_2O_3$-16.74%<br>$Fe_2O_3T$-11.63%<br>[$Fe_2O_3$ 1.74%]<br>[FeO 8.90%]<br>MnO-0.17%<br>MgO-5.83%<br>CaO-8.60%<br>$Na_2O$-3.53%<br>$K_2O$-1.84%<br>$P_2O_3$-1.22% | Epistemic |
| $^{137}$Cs analyses for Fortymile Wash alluvial fan | Analytical concentrations of $^{137}$Cs in samples from locations on different geomorphic features on a major YMR drainage alluvial fan. | DTN: LA0308CH831811.002 [DIRS 164853] | $^{137}$Cs analyses range from 0.002 to 0.322 pCi/gram | Epistemic |
| Tephra thicknesses, Lathrop Wells volcano | Thicknesses of explosive tephra deposits at different map locations in vicinity of Lathrop Wells volcano. | DTN: LA0305DK831811.001 [DIRS 164026] | Tephra thicknesses at various map points range from 1 to 304 cm | Epistemic |

### 6.5.1.2 Forty-five Chemical Analyses of Products from the Lathrop Wells Volcano

There is a low degree of uncertainty associated with the mean chemical composition of Lathrop Wells volcano lava; the uncertainty is quantitatively provided in the statistical information in Table 6-2. These data are used to estimate physical properties of a future magma (of similar composition) as it ascends through the crust, intercepts and interacts with the repository, and erupts onto the surface. The statistics provided in Table 6-2 for the major element chemical composition data reflect the natural variations expected among multiple samples of the same lava flow, as well as the variations expected for multiple samples from different lava flows from the same monogenetic volcanic event. There is a very low degree of uncertainty associated with any one major oxide determination because of the tight clustering of values (reflected in their standard error and standard deviation) among 45 rock samples and the use of modern analytical methods of chemical analysis. Additional analyses would only serve to decrease the standard deviations of any one mean.

Wohletz, K.H. 1986. "Explosive Magma-Water Interactions: Thermodynamics, Explosion Mechanisms, and Field Studies." *Bulletin of Volcanology, 48,* 245-264. Berlin, Germany: Springer-Verlag. TIC: 225183. 140956

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Wylie, J.J.; Helfrich, K.R.; Dade, B.; Lister, J.R.; and Salzig, J.F. 1999. "Flow Localization in Fissure Eruptions." *Bulletin of Volcanology, 60,* (8), 432–440. New York, New York: Springer-Verlag. TIC: 254054. 162861

Yoder, H.S., Jr. and Tilley, C.E. 1962. "Origin of Basalt Magmas: An Experimental Study of Natural and Synthetic Rock Systems." *Journal of Petrology, 3,* (3), 342-532. London, England: Oxford University Press. TIC: 247024. 122589

## 8.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

10 CFR 63. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Readily available. 156605

AP-2.22Q, Rev. 1 ICN 0, *Classification Criteria and Maintenance of the Monitored Geologic Repository Q-List* 164786

AP-SIII.2Q, Rev. 1 ICN 2, *Qualification of Unqualified Software* 169197

AP-SIII.9Q, Rev. 1 ICN 7, *Scientific Analyses* 169151

LP-SI.11Q-BSC, Rev. 0 ICN 0, *Software Management* 168412

## 8.3 SOURCE DATA, LISTED BY DATA TRACKING NUMBER

LA000000000099.002. Major Element, Trace Element, Isotopic, and Mineral Chemistry Data from Lathrop Wells. Submittal date: 08/02/1995. 147725

LA0009FP831811.001. Compilation and Summaries of Data Supporting Computation of Volcanic Event Intersection Frequencies. Submittal date: 09/01/2000. 164712

LA0302CH831811.002. Ash Redistribution, Lava Morphology, and Igneous Process Studies SITP-02-DE-001, REV 00A. Submittal date: 02/18/2003. 162863

LA0302GH831811.002. Grain Size of Tephra from Tephra Deposits Around the 162864

**Acceptance Criterion 3: Data uncertainty is characterized and propagated through the model abstraction**

1. Models use parameter values, assumed ranges, probability distributions, and bounding assumptions that are technically defensible, reasonably account for uncertainties and variabilities, do not result in an under-representation of the risk estimate, and are consistent with the characteristics of the reasonably maximally exposed individual.

   Item 1, for Acceptance Criterion 1, describes the information provided in this report that is relevant to the analysis of ash deposition and redistribution from an eruption at a Yucca Mountain repository. The report does not address the representation of the risk estimate, nor does it address the characteristics of the reasonably maximally exposed individual in 10 CFR 6 Part 63.

2. The technical bases for the parameter values and ranges in the total system performance assessment abstraction are consistent with data from the Yucca Mountain region [e.g., Amargosa Valley survey (Cannon Center for Survey Research 1997)], studies of surface processes in the Fortymile Wash drainage basin, applicable laboratory testing, natural analogs, or other valid sources of data. For example, soil types, crop types, plow depths, and irrigation rates should be consistent with current farming practices, and data on the airborne particulate concentration should be based on the resuspension of appropriate material in a climate and level of disturbance similar to that which is expected to be found at the location of the reasonably maximally exposed individual during the compliance time period.

   Item 1, for Acceptance Criterion 1, describes the information provided in this report that is relevant to the analysis of ash deposition and redistribution from an eruption at a Yucca Mountain repository. Studies specific to the Fortymile Wash drainage are described in Sections 6.3.4, and 6.3.4.1. Effects of storms and climate changes on natural soil redistribution processes are described in Section 6.3.4.3. The report does not address biosphere topics of crop types, plow depths, irrigation rates, current farming practices, or airborne particulate concentrations.

3. Uncertainty is adequately represented in parameters for conceptual models, process models, and alternative conceptual models considered in developing the total system performance assessment abstraction of redistribution of radionuclides in soil, either through sensitivity analyses, conservative limits, or bounding values supported by data, as necessary. Correlations between input values are appropriately established in the total system performance assessment.

   Item 1, for Acceptance Criterion 1, describes the information provided in this report that is relevant to the analysis of ash deposition and redistribution from an eruption at a Yucca Mountain repository. Uncertainties associated with tephra thicknesses for the Lathrop Wells volcano are described in Section 6.5.1.5. Uncertainties associated with $^{137}Cs$ analyses for the Fortymile Wash alluvial fan are described in Section 6.5.1.3. Alternative conceptual located at several elevations in the cone. The elevations recorded with each measurement accurately reflect relative stratigraphic position (lower elevation represents earlier cone history; higher elevations represent later cone history). Measurements of lithic clasts were made in nonwelded deposits of coarse ash, lapilli, and larger material. They are not indicative of the stratigraphically lower, short pulse of hydrovolcanic activity recorded in deposits outside the cone (Section C3.3, Figure C-11; Wohletz 1986 [DIRS 140956], p. 258). Counts were made with 12X and 10X hand lenses. Each visible lithic clast more than or equal to 1 mm was identified and its short and long axis measured. Lithic clast volume fractions *F* were determined using the following equation (Valentine and Groves 1996 [DIRS 107052], p. 80):

$$F = (\text{area fraction})^{3/2}\,(1.18)^3 \qquad \text{(Eq. C-1)}$$

where areas measured are 1 m by 1 m squares on vertical exposures. Measured lithic clast abundances range from 0.91 vol% to less than 0.018 vol%. The volume data indicate that lithic-clast abundance is greatest within the measured lower stratigraphic levels in the scoria cone and decreases one to two orders of magnitude in overlying, younger scoria intervals (Figure C-7). The lithic clasts production during eruption was not uniform throughout the cone construction period, and the variation suggests less vigorous conduit enlargement with time. This observation is tempered with the recognition that much of the scoria (and included lithic clasts) within volcanic cones is subject to avalanching, slumping, and redeposition during construction (McGetchin et al. 1974 [DIRS 115469], p. 3268).

Table C-2. Lithic Clast Measurements in the Lathrop Wells Scoria Cone

| Patch | Elevation (ft) | Volume Fraction | |
|---|---|---|---|
| 17 | 3146 | 0.000140 | |
| 15 | 3136 | 0.000200 | |
| 12 | 3119 | 0.000160 | |
| 14 | 3106 | 0.000029 | |
| 13 | 3079 | 0.000083 | |
| 18 | 3074 | 0.000940 | |
| 16 | 3056 | 0.000290 | |
| 11 | 2940 | 0.000039 | |
| 7 | 2926 | 0.006700 | Mean (7-10) = 0.004985 |
| 8 | 2926 | 0.000940 | |
| 9 | 2926 | 0.008700 | |
| 10 | 2924 | 0.003600 | |
| 1 | 2886 | 0.009100 | Mean (1-6) = 0.002899 |
| 2 | 2886 | 0.005800 | |
| 3 | 2886 | 0.000075 | |
| 4 | 2886 | 0.001300 | |
| 5 | 2886 | 0.001100 | |
| 6 | 2886 | 0.000018 | |

Source: DTN: LA0302GH831811.003 [DIRS 162865].

NOTE: Lithic clast measurements were done in eighteen 1-m$^2$ areas in Lathrop Wells scoria cone outcrops. Elevations reflect relative stratigraphic position (early to late cone activity), as explained in the text. Mean values are calculated for samples collected at the same or similar elevation. Multiply the volume fraction by 100 to obtain a percentage.